Pressurized Fabric Structures: Applications and Mechanics Research

The Ninth Annual JLOTS

Logistics-from-the-Sea Symposium

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Airbeam Technology

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- Load Bearing Pressurized Fabric Structures
- Pressurization pre-tensions the fibers, creating a structure that is rigid under design loads, but deflects without damage when overloaded.
- Achieves outstanding strength-to- weight ratios.

Shelter Technology

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- Replace metal structural frame shelters with inflatable arches or “airbeams” to provide:
  - Rapid, Easy Deployment
  - Reduce Weight
  - Low Cube
- Available in widths ranging from 20 feet to 85 feet for applications such as command/control, medical, vehicle/aircraft maintenance

Manufacturing Technology

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Braiding Technology

Weaving Technology

- Two new textile technologies produce seamless tubular braided or woven fabrics with high pressure capacity (30-80 psi)
- Curvature and bending resistance are obtained by using coated high-tenacity fibers and controlling fiber orientation.

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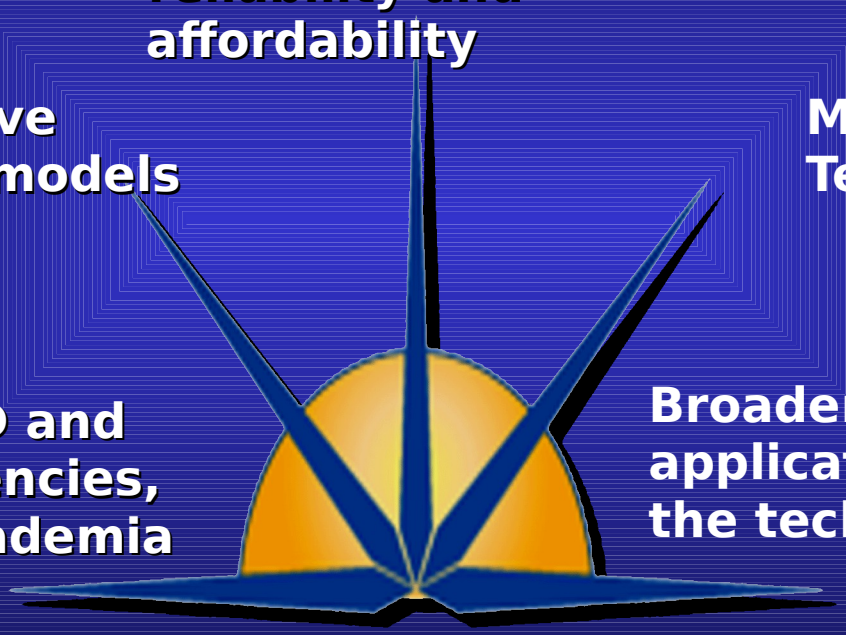
(Established in 2001 at the Natick Soldier Center in Natick, MA)

Increase durability, reliability and affordability

Establish predictive design tools and models

Market and Document Technology



Partner with DoD and government agencies, industry, and academia

Broaden inflatable structure applications and commercia the technology

Vision

Deliver new shelter technology into the hands of soldiers and commercial users.

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New Shelter Technology

Future Medical Shelter System

- 4 Airbeams, 14 inches in diameter
- Internal Air Beam Pressure 60 psi
- Clear Floor Area: 1750 sq. ft.
- De 20 minu

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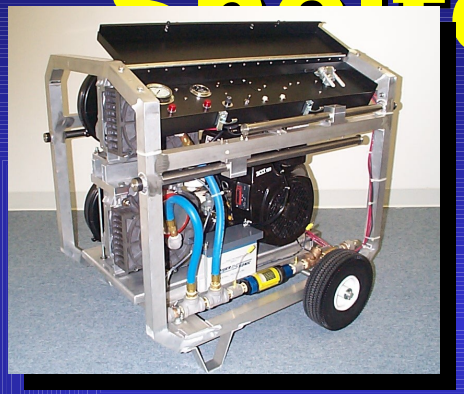
Rapid Inflation System for Airbeam Shelters

Successfully Tested Prototypes

Oil-flooded Screw Compressor



Oil-free Scroll Compressor

Oil-free Wobble Piston Compressor

Objective MET

Increase capacity, by a factor of five, over commercially available, portable air compressors, through the use of innovative engineering design, lightweight materials, and high-speed components

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Durability, Reliability, Affordability

- **Durable**

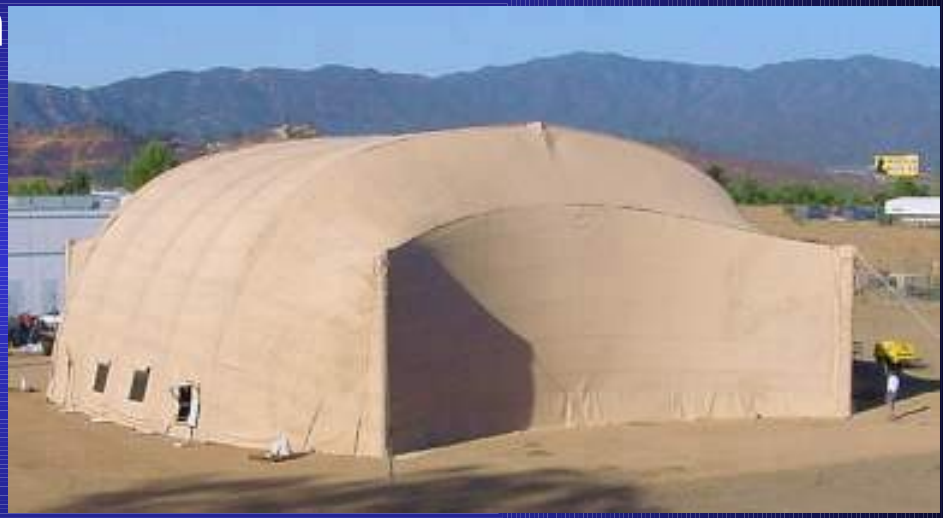
Puncture and Small Arm Resistant

- **Reliable**

Pressure Check Weekly

- **Affordable**

New Manufacturing Technology Achieved Significant Cost Reduction



Aviation Inflatable Maintenance Shelter at Hollom AFB

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Broaden Applications

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Army

Extended Range Aerial Delivery System (ERADS)

Remote controlled glider

that delivers cargo to troops on the ground

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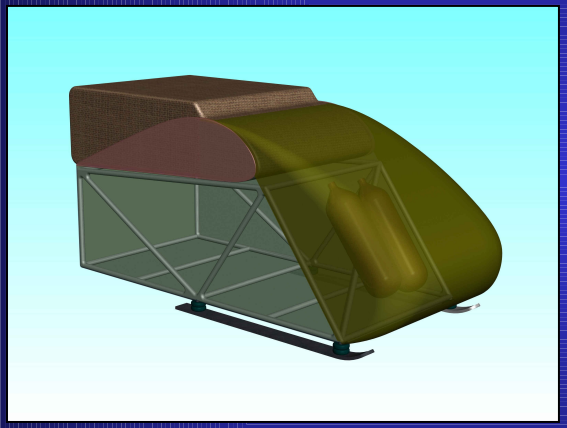
Broaden Applications Extended Range Aerial Delivery System



Configuration in aircraft (Pre-deployment)

Inflatable tubes form the wing

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Broaden Applications

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Inflatable Ladder

- Weighs 55 lbs
- Inflation Pressure of 40 psi

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Broaden Applications

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NASA

Quickly Deployable Space Structures

- **Inflatable Boom on a Solar Sail**

- **Inflatable Telescopes**

Commercialize the Technology
Air Beam Shelter in Production

Chemical Biological Protection Shelter (CBPS)

64 currently deployed in Iraq

Federal Fabrics – Fibers, Lowell, MA
Designed & Produces Airbeam Frames

Saint - Gobain, Merrimack, NH
Designed & Produces - Softwall Shelter

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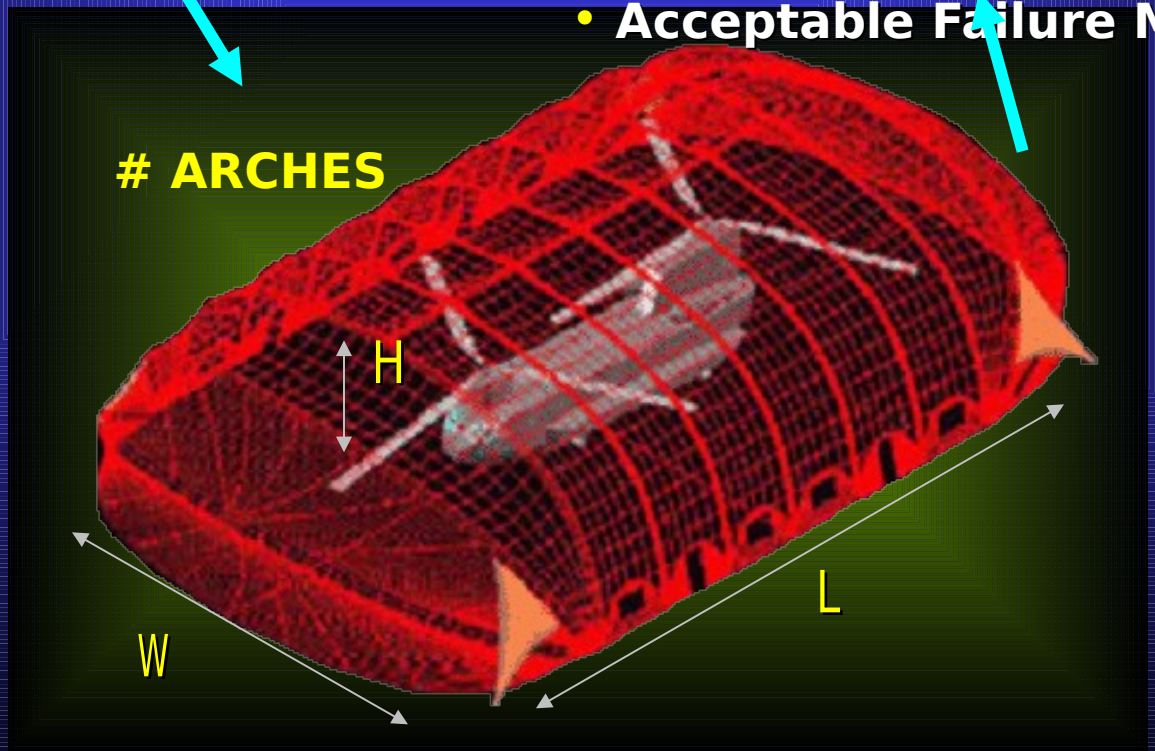
Air Beam Structural Design

GIVEN

- Floor length & width
- Minimum height requirement
- Environmental Loadings

DETERMINE

- # Air beams / arches
- Diameter
- Safe operating pressure
- # Warp & weft tows per unit length
- Fiber material(s)
- Coating material
- Acceptable Failure Modes



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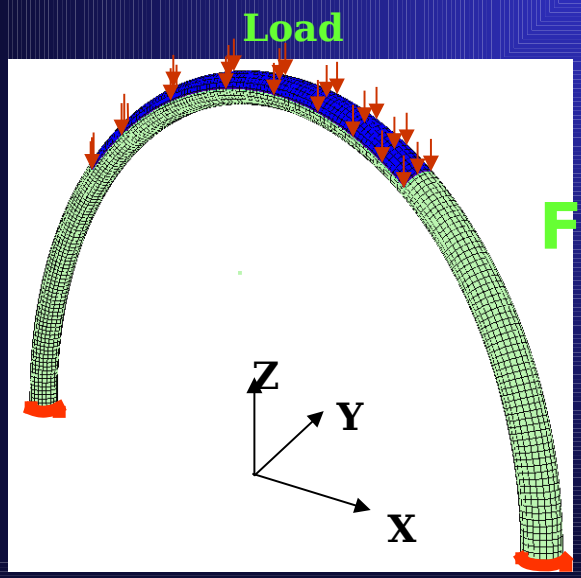
Predictive Tools for Structural Analysis

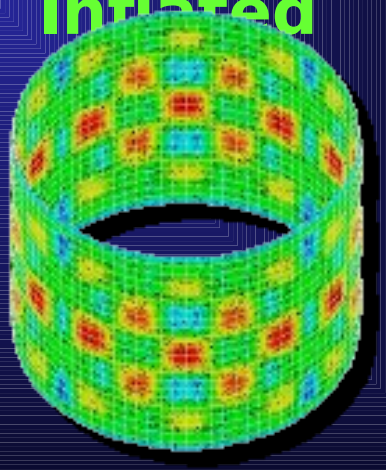
Dual Approach

- Predict Structural Response of Air Beam (Wind and Snow Loads)
- Predict Material Behavior



Fabric

Fabric



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Structural Analysis

Modeling Airbeam Structures

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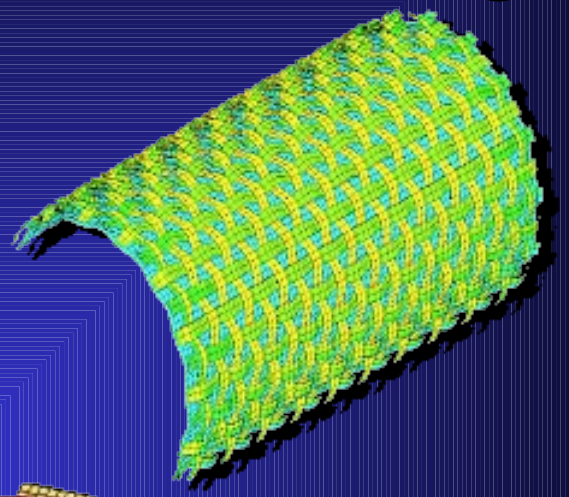
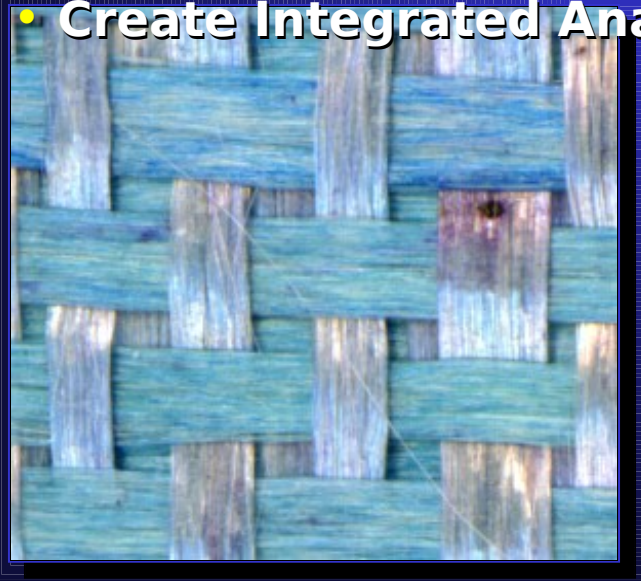
Modeling Goals

- Develop 3D Braiding & Weaving Models
- Scalable Verification Instrument
- Collect and Analyze Empirical Test Data
- Create Integrated Analytical [illegible]





Advantages

- Analyze Design Problems
- Technology Investment

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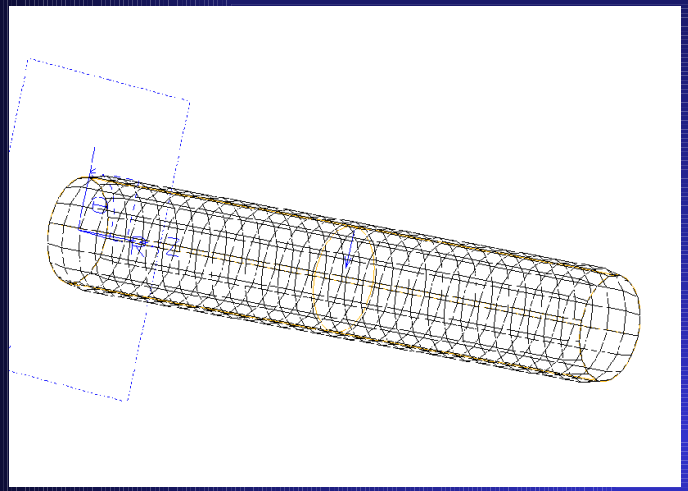
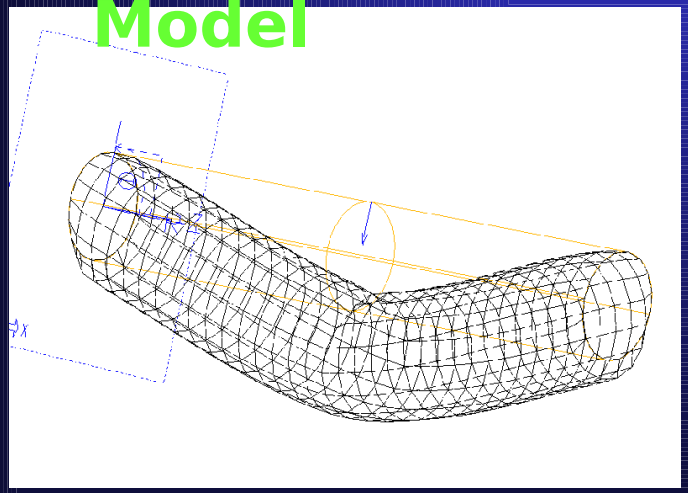
Element Assumptions and Formulation



Nastran Model



A specialized structural air beam element for inflatable structures

- Nonlinear fabric mechanics
- Modeling work done by inflation pressure
- Need to predict folding and wrinkling of fabric
- Ease of use when modeling a fabric shelter

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4-Pt. Flexure Tests on Woven Vectran Air Beams

4-Point Bend Fixture Mounted in Instron® with Displacement Wire Transducer Used To Capture Mid-Span Deflection (5 oz. constant tension force)

Construction Details

- 3000 denier Vectran
- 13 warps/inch
- 13 wefts/inch
- $Strength_{Vectran}$ = 28 gpd
- Bladder: Estane 58315 TPU
- $Bladder_{thick}$ = 0.008”
- Uncoated
- End Cap: Stitched-on
- Mfg. by Federal Fabrics/Fibers, Lowell MA
- Diameter = 6 in; Length

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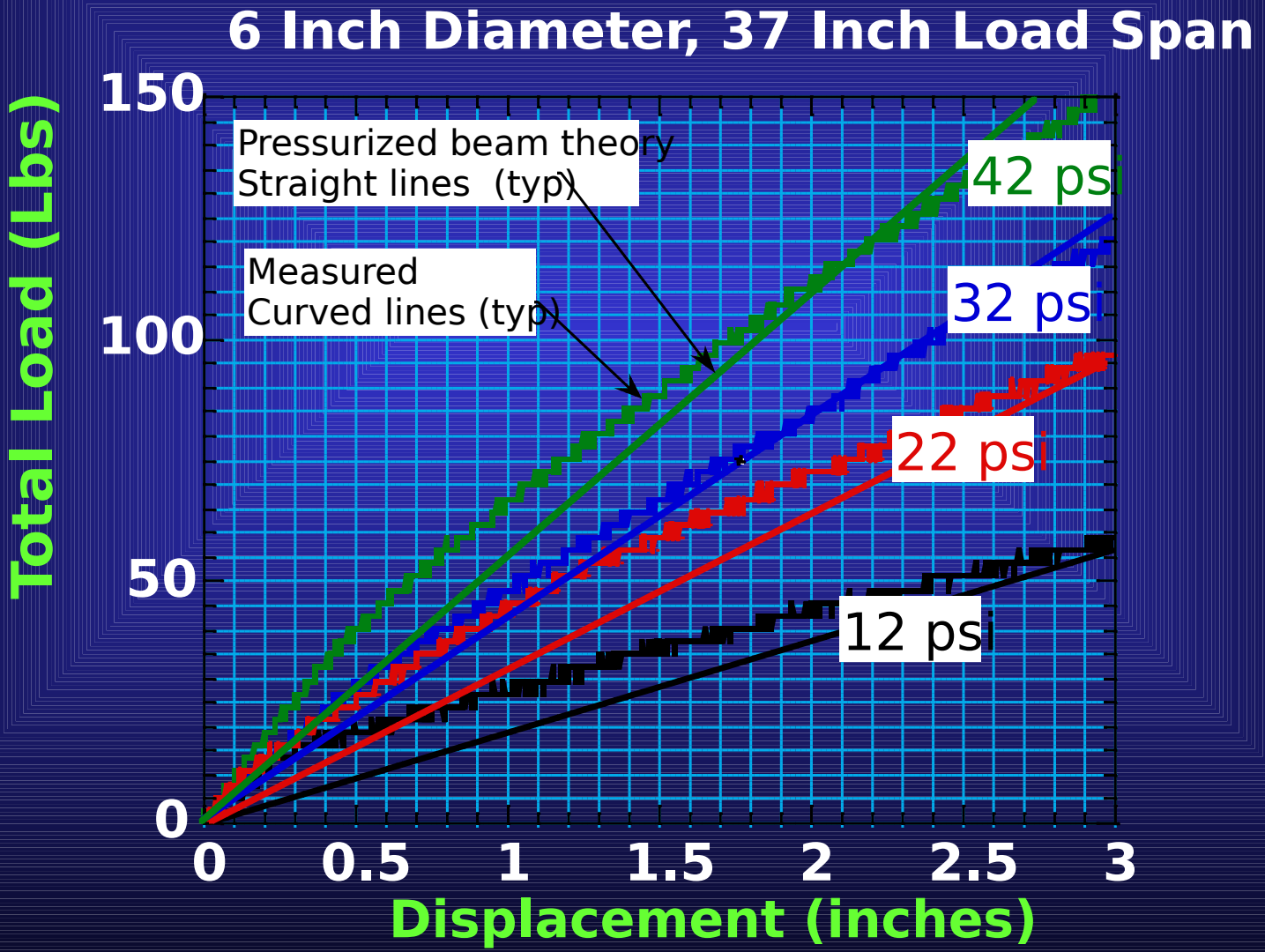
Comparison of Finite Element and Experimental Results



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Fabric Mechanics Modeling

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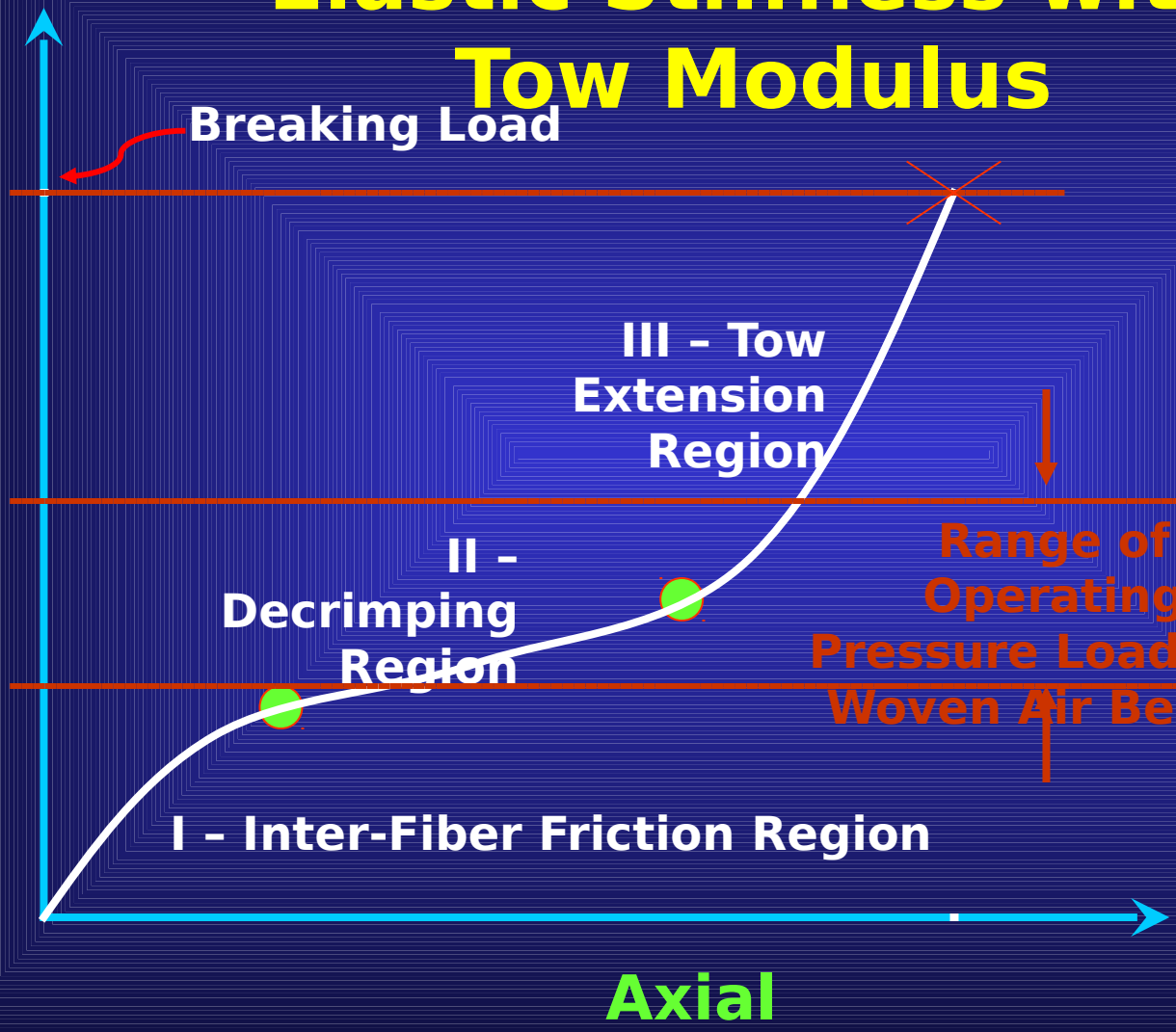
Invariance of Fabric Elastic Stiffness with Tow Modulus


Breaking Load
III – Tow Extension Region
II – Decrimping Region
Range of Operating Pressure Loads for Woven Air Beams
I – Inter-Fiber Friction Region
Axial Load
Axial Displacement

[See Hearle, J.W.S. et al., Structural Mechanics of Fibers, Yarns and Fabrics, Vol. I, 1969 Wiley & Sons, NY., p. 340.]

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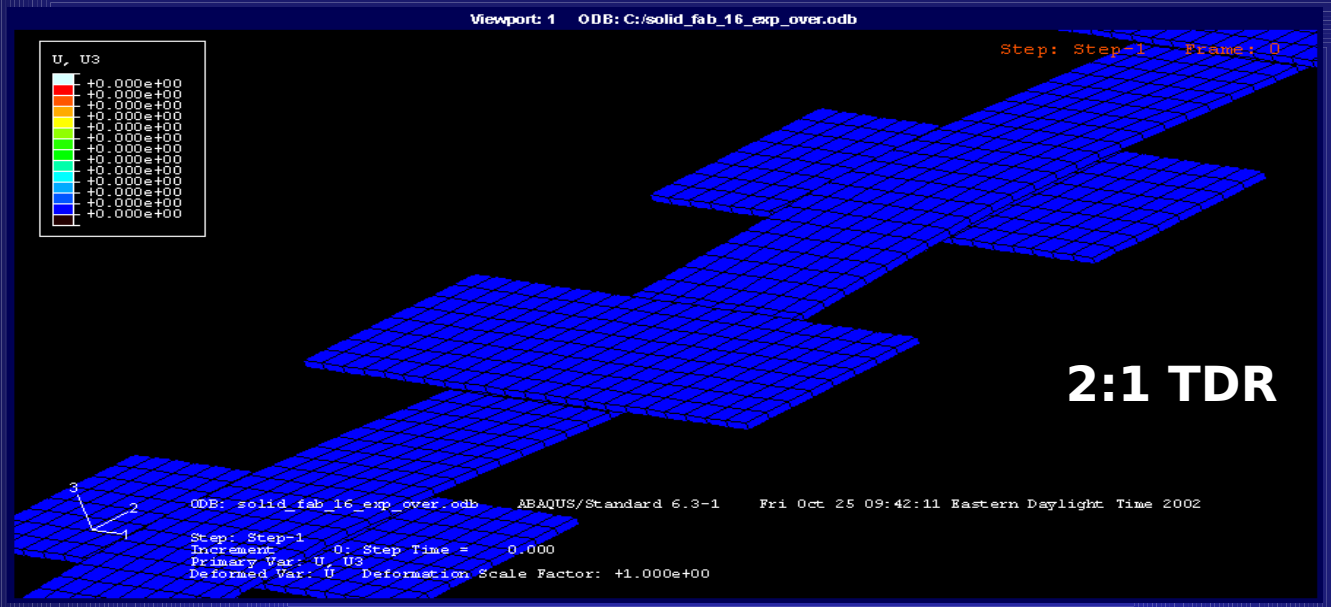
Fabric Strip Model Description



- **ABAQUS® Finite Element Analysis Software**
- **Full surface-to-surface contact of all tows**
- **Typical run times: 3-4 hrs.**

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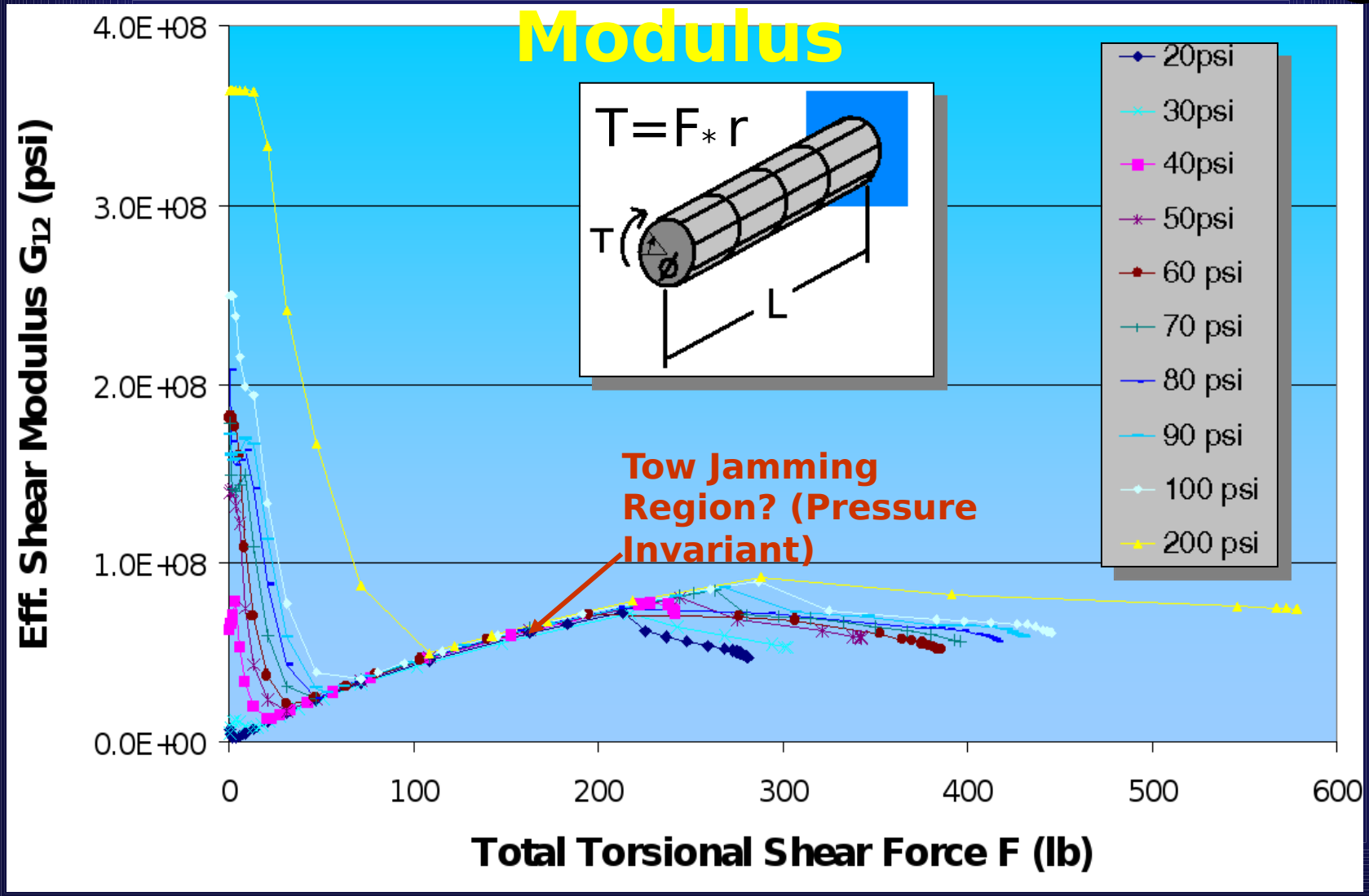
Pressure & Load Dependent Shear Modulus



(2:1 TDR, 1:1 Equi-Biaxial Loading Ratio With Hoop Tow Spacing = 0.0472”)

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Stages of Pure Shearing Deformations

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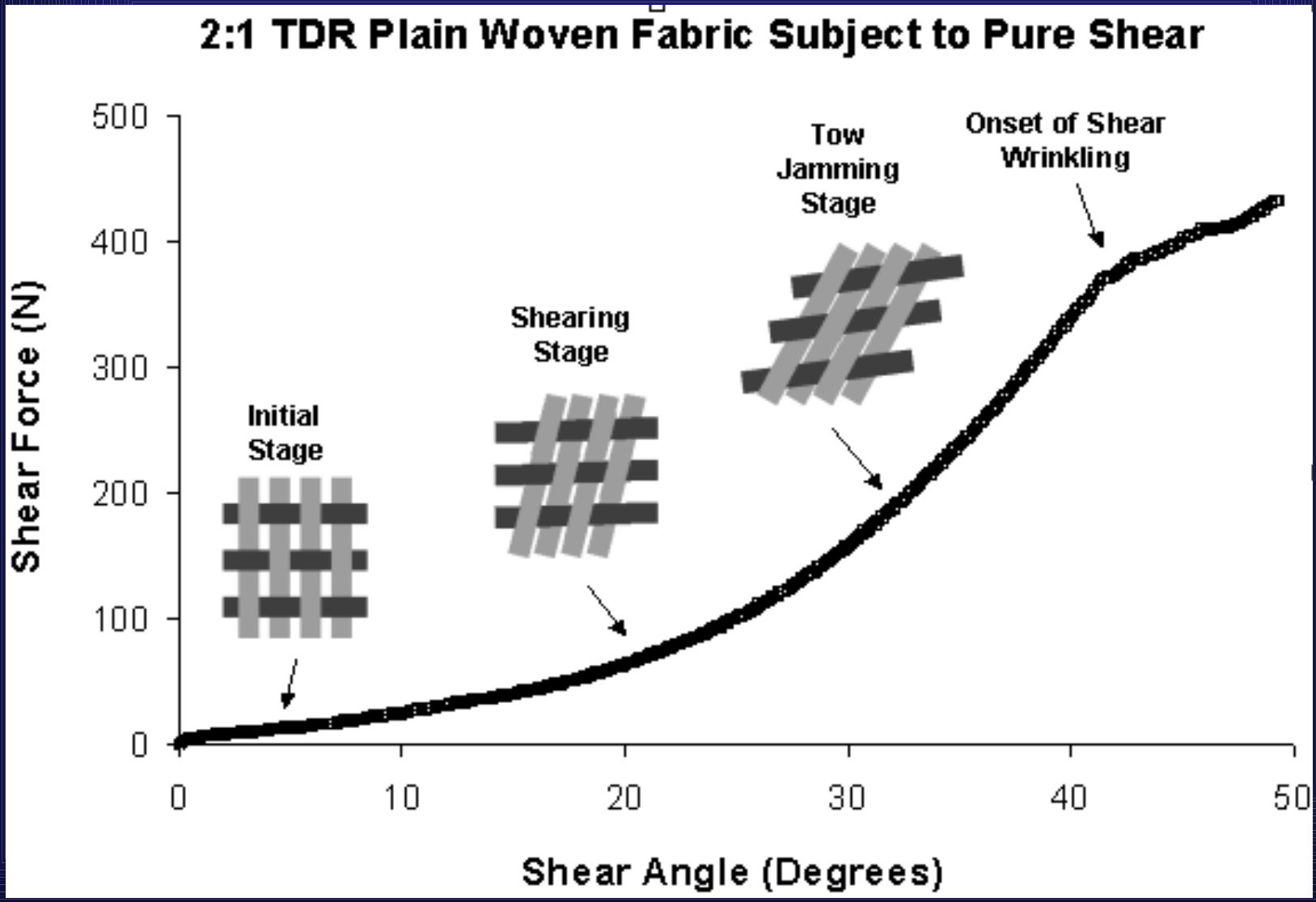

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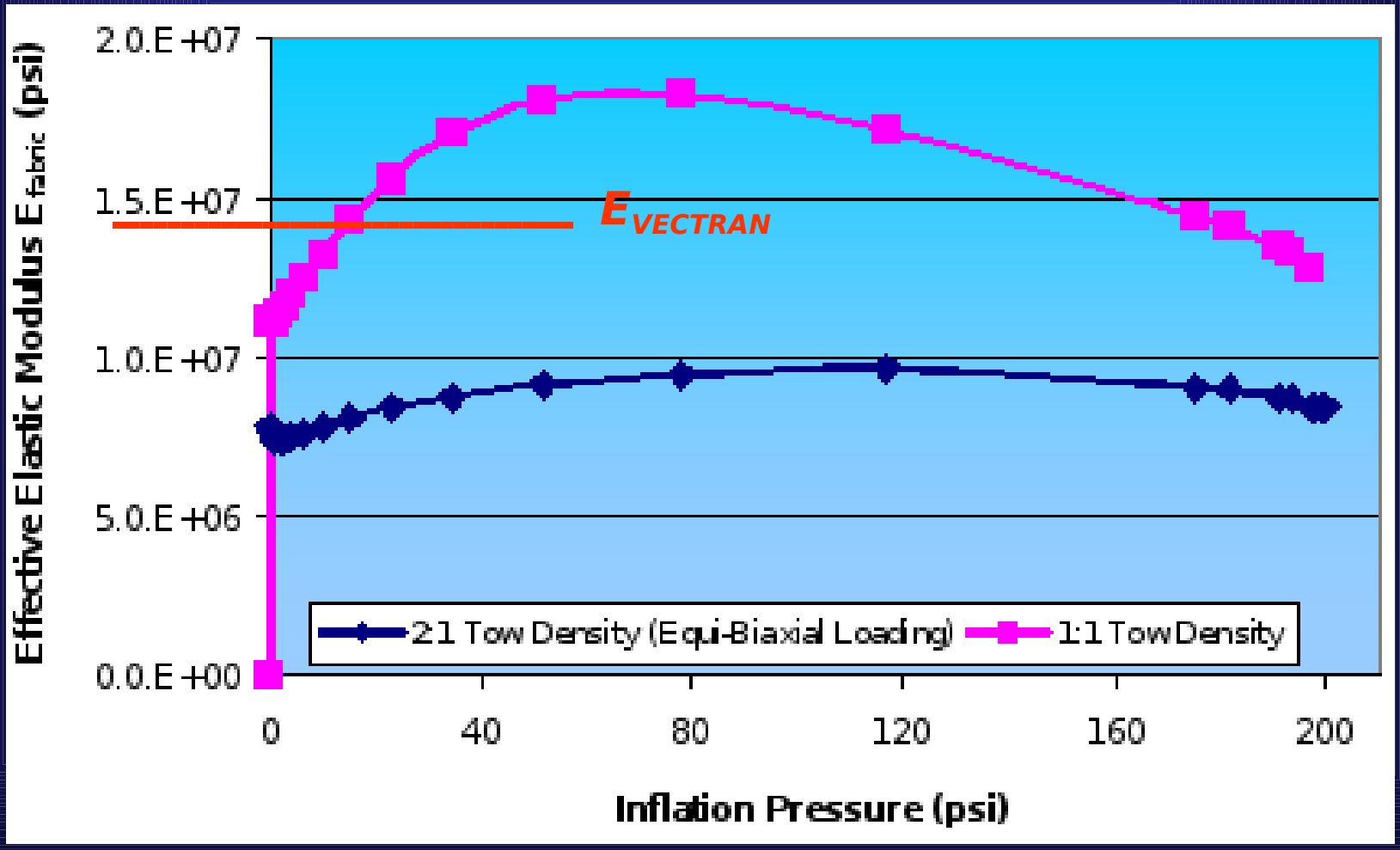
Fabric Elastic Modulus As Functions of Pressure & TDR



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Summary

- **Inflated structures are:**
  - **proven to be durable and reliable**
  - **more affordable**
  - **(Cost reduction is an ongoing process.)**
  - **sustaining our troops in Iraq**
- **Modeling efforts predict structural behavior and inflated fabric properties.**
- **Experimental validation efforts are underway.**

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Fiber Innovations inc.

COLLECTIVE PROTECTION SHELTERS

Yankee Scientific, Inc.

City College CUNY, NY

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